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Antioxidant and Antimicrobial Activities of Coffee Husk, Cherry, Raw and Roasted Coffee Extracts Using Supercritical Fluid and Sonication Extraction Methods

Pojchanad Pathaburee[1*], Utai Thaicharoen[1], Wachiraporn Pisitaro[1]

Office Of Scientific Instrument and Testing, Prince of Songkla University, Hat Yai, Songkhla[1]

Corresponding Author: 1*

ABSTRACT— This study investigated the antioxidant and antimicrobial properties of coffee husk, cherry, raw coffee, and coffee beans roasted at different levels. Extracts were prepared using supercritical fluid extraction (SFE) and sonication. Antioxidant activity was assessed by DPPH assay, and antimicrobial activity was evaluated against *Staphylococcus aureus*, *Escherichia coli*, *Enterobacter* sp., and *Bacillus cereus* using the agar well diffusion method. Dark coffee extracted by sonication exhibited the highest antioxidant activity (IC_{50} = 0.0549 mg/mL). Raw coffee extracted by sonication showed the strongest inhibition against *S. aureus*, while shell extract by sonication inhibited *E. coli* most effectively. Medium coffee extract by sonication demonstrated the highest activity against Enterobacter, and shell extract by SFE showed the best activity against *B. cereus*. These results highlight the influence of coffee type, roasting, and extraction method on bioactive properties.

KEYWORDS: Coffee husk, roasted coffee, antioxidant activity, antimicrobial activity, supercritical fluid extraction

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1. INTRODUCTION

Coffee (Coffea spp.) is one of the most widely consumed beverages worldwide and represents a major source of bioactive compounds such as phenolic acids, flavonoids, alkaloids, and amino acids, which contribute to its health-promoting properties [1], [22], [16], [8]. In addition to coffee beans, by-products such as husks and cherries contain significant levels of phenolics, caffeine, and other compounds with antioxidant and antimicrobial potential [2], [10], [10]. Roasting induces complex chemical transformations, including the formation of Maillard reaction products and melanoidins, which can enhance antioxidant activity but may also degrade thermolabile compounds [3], [11], [19], [12]. Extraction methods strongly influence the recovery of bioactive compounds. Supercritical fluid extraction (SFE) is known for its selectivity and ability to yield high-purity extracts with minimal solvent residue [25]. whereas sonication enhances solvent penetration, improving phenolic extraction efficiency [5], [4]. The aim of this study was to systematically compare the antioxidant and antimicrobial activities of coffee husk, cherry, raw coffee, and roasted beans extracted by SFE and sonication, and to identify combinations most suitable for functional food and nutraceutical development.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Coffee husk, cherry, raw beans, medium roast, and dark roast Robusta coffee were obtained from Saba Yoi District, Songkhla Province, Thailand. Samples were dried at 50 °C, ground,

2.2 Extraction Methods

2.2.1 Supercritical Fluid Extraction (SFE)

Samples were extracted using supercritical CO_2 at 40 MPa and 50°C for 120 min. Extracts were collected, concentrated under reduced pressure, and stored at 4°C.

2.2.2 Sonication Extraction

Samples were suspended in 70% ethanol and sonicated at 40 kHz for 60 min. Extracts were filtered, concentrated under reduced pressure, and stored at 4°C.

2.3 Antioxidant Activity

The DPPH radical scavenging assay was conducted to determine IC_{50} values according to Brand-Williams et al. (1995). [6]

2.4 Antimicrobial Activity

Antimicrobial activity against *S. aureus, E. coli, Enterobacter* sp., and *B. cereus* was measured using the agar well diffusion method [7]. Zones of inhibition (mm) were recorded.

3. RESULTS AND DISCUSSION

3.1 Antioxidant Activity

The antioxidant capacities of the coffee extracts, expressed as IC_{50} values, are summarized in Table 1. Sonication extraction consistently produced extracts with lower IC_{50} values compared to SFE, indicating superior radical scavenging activity. Among all samples, dark roasted coffee extracted by sonication exhibited the strongest antioxidant potential with an IC_{50} of 0.0549 mg/mL, followed by raw coffee (0.1312 mg/mL) and coffee husk (0.2151 mg/mL). In contrast, SFE-derived extracts generally showed weaker antioxidant effects, particularly in raw coffee (IC_{50} = 0.5315 mg/mL) and cherry (0.5267 mg/mL).

These findings suggest that both the extraction method and roasting level markedly affect antioxidant activity. The enhanced antioxidant potential of dark roast is likely attributed to the formation of Maillard reaction products and melanoidins during roasting, which are known contributors to radical scavenging activity [20], [14], [17]. Similar trends have been reported in previous studies, highlighting the role of thermal processing in generating bioactive compounds that improve antioxidant efficiency.

3.2 Antimicrobial Activity

The antimicrobial effects of coffee extracts against *Staphylococcus aureus, Escherichia coli, Enterobacter* sp., and *Bacillus cereus* are presented in Table 1. Distinct inhibitory patterns were observed depending on the extraction method and coffee matrix. Raw coffee extracted by sonication showed the most pronounced inhibition against S. aureus (15.48 mm), whereas coffee husk (sonication) exhibited the strongest activity against *E. coli* (13.24 mm). Medium roasted coffee (sonication) demonstrated the highest inhibition against *Enterobacter* (14.92 mm). Interestingly, coffee husk obtained via SFE displayed the most effective inhibition against B. cereus (14.29 mm).

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Overall, sonication extracts tended to exhibit stronger and broader antimicrobial activities compared to SFE extracts, supporting the idea that ultrasonic-assisted extraction facilitates higher recovery of phenolic compounds and caffeine, both of which contribute to antimicrobial efficacy. These results are consistent with previous findings that reported coffee-derived phenolics and alkaloids as key determinants of antimicrobial action [9], [20], [10]. The observed selectivity of different coffee matrices toward specific bacterial strains also reflects matrix-dependent variations in bioactive compound composition, highlighting their potential applications in functional foods and natural antimicrobial agents.

Sample	Extraction	IC50	*S. aureus*	*E. coli*	Enterobacter	*B. cereus*
Cherry	SFE	0.5267	12.877	11.44	13.193	14.186
Medium Coffee	SFE	0.3957	13.155	9.894	9.485	9.67
Coffee Husk	SFE	0.5216	9.973	11.943	13.417	14.289
Raw Coffee	SFE	0.5315	12.274	11.291	11.902	13.752
Dark Coffee	SFE	0.1976	8.406	7.847	7.777	8.267
Cherry	Sonication	0.4486	12.091	11.677	14.083	11.839
Coffee Husk	Sonication	0.2151	12.1	13.244	14.049	8.655
Medium Coffee	Sonication	0.2989	13.723	12.255	14.922	12.936
Raw Coffee	Sonication	0.1312	15.484	9.478	11.937	13.015
Dark Coffee	Sonication	0.0549	11.105	12.415	7.633	10.454

4. CONCLUSION AND RECOMMENDATION

This study demonstrated that both the extraction method and coffee matrix significantly influenced the antioxidant and antimicrobial properties of coffee-derived extracts. Sonication consistently enhanced the recovery of bioactive compounds compared to supercritical fluid extraction (SFE), yielding extracts with superior radical scavenging activity. Dark roasted coffee obtained by sonication exhibited the strongest antioxidant potential (IC_{50} = 0.0549 mg/mL), confirming the contribution of Maillard reaction products and melanoidins formed during roasting.

In terms of antimicrobial activity, the efficacy varied depending on coffee type and bacterial strain. Raw coffee (sonication) was most effective against Staphylococcus aureus, coffee husk (sonication) showed the highest inhibition against *Escherichia coli*, medium roasted coffee (sonication) was most active against Enterobacter sp., while husk extract (SFE) demonstrated the strongest inhibition against *Bacillus cereus*. These findings highlight the selective antimicrobial potential of coffee extracts, reflecting the unique composition of phenolics, alkaloids, and Maillard-derived compounds in different matrices [1], [18], [24].

Overall, coffee by-products such as husks and cherries represent promising natural sources of antioxidants and antimicrobials. The results suggest potential applications of these extracts in the development of functional foods, nutraceuticals, and natural preservatives, thereby supporting the valorization of coffee processing by-products into high-value bioactive ingredients.

Future Perspectives

Further studies should focus on identifying and characterizing the specific bioactive compounds responsible for the observed antioxidant and antimicrobial effects, particularly phenolic acids, alkaloids, and Maillard reaction products. In addition, in vivo studies and toxicity evaluations are necessary to confirm the safety and efficacy of these extracts for human consumption [21], [26], [3] Coffee by-product utilization into industrial food systems could contribute to sustainable production while reducing agricultural waste [27], [23] (Ultimately, the development of standardized coffee-based nutraceuticals and natural preservatives may open new opportunities in the food, pharmaceutical, and cosmetic industries nutraceutical applications [28- 30], [28]

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